

## A Newly Recorded Basket Star of Genus *Gorgonocephalus* (Ophiuroidea: Euryalida: Gorgonocephalidae) from the East Sea, Korea

Donghwan Kim, Sook Shin\*

Department of Life Science, Sahmyook University, Seoul 01795, Korea

### ABSTRACT

Euryalid specimens were collected from Gonghyeonjin and Daejin, Gangwon-do in the East Sea, Korea at a depth of 250–300 m by fishing nets on November 2013 and August 2014. They were identified as *Gorgonocephalus arcticus* Leach, 1819 belonging to family Gorgonocephalidae of order Euryalida, which was new to the Korean fauna. Nucleotide sequences of partial mitochondrial cytochrome c oxidase I (mt-COI) gene, which was 569 bp in length, were compared among four *Gorgonocephalus* species, and were subsequently employed to reconstruct phylogenetic trees using the MP, ML, and BI methods. As a result, no sequence difference was found between the *G. arcticus* mt-COI gene sequences from Korea and Canada, and the two made a strong monophyletic group. With the newly recorded *G. arcticus* in Korea, in total, four *Gorgonocephalus* species have been reported in Korea.

**Keywords:** *Gorgonocephalus arcticus*, taxonomy, molecular phylogenetic analyses, mitochondrial COI gene

### INTRODUCTION

Family Gorgonocephalidae, comprising 34 genera, is the largest of three families belonging to order Euryalida (Stöhr, 2015), and its four genera (*Astroboa*, *Astrocladus*, *Astrodermum*, and *Gorgonocephalus*) have been reported in Korean fauna (Shin and Rho, 1996; Shin, 2013). Species of this family have very branched five arms and have rings of little hook-like spines forming bands around the branches of each arm. Almost all *Gorgonocephalus* species are exclusively distributed in deep water and are of worldwide distribution (Piepenburg, 2000). This genus has special features such as the presence of arm spines before the first arm fork of arms, disk and arm covered with small stumps or tubercles, disk often naked interradially (Baker, 1980), and the presence of a row of marginal plates on the interbranchial outer margin (Matsumoto, 1917). A family-level revision of order Euryalida based on sequences from mitochondrial genes (16S rRNA and cytochrome c oxidase I [COI]) and a nuclear gene (18S rRNA) from 83 euryalid ophiuroids including *G. chilensis*, *G. eucnemis*, *G. pustulatum*, and *G. tuberosus* was investigated (Okanishi and Fujita, 2013). Only three (*G. dolichodactylus*, *G. eucnemis*, and *G. tuberosus*) of 10 *Gor-*

*gonocephalus* species have been reported in Korea based on their morphology (Shin, 2013; Kim and Shin, 2015).

Some basket stars were collected from Gonghyeonjin and Daejin, Gangwon-do in the East Sea, Korea at a depth of 250–300 m by fishing nets on November 2013 and August 2014. The specimens were preserved in 95% ethyl alcohol and identified on the basis of morphological characteristics and molecular analyses. The important morphological characteristics were photographed using a digital camera (Nikon D7000, Tokyo, Japan), stereo-microscope (Nikon SMZ 1000), and scanning electron microscope (JEOL JSM-6510, Tokyo, Japan). The sequences of mitochondrial cytochrome c oxidase I (mt-COI) gene were analyzed with newly intended primers (F-TGRGCYGGVACMRYDGGAAACHGC and R-GGRTCHCKCCHC CHGWDGGRTC) for the accurate molecular identification of Korean *Gorgonocephalus* species. DNA was extracted using DNeasy Tissue and Blood Kits (Qiagen, Hilden, Germany), and PCR and phylogenetic analyses were conducted according to Lee and Shin (2011) with minor revision. The phylogenetic trees were inferred from their alignment sequences by maximum parsimony (MP), maximum likelihood (ML), and Bayesian inference (BI) methods. They were identified as *Gorgonocephalus arcticus*

Leach, 1819, which is reported for the first time in Korea. These specimens are deposited in the Marine Echinoderm Resource Bank of Korea (MERBK), Sahmyook University, Seoul, Korea.

## SYSTEMATIC ACCOUNTS

Class Ophiuroidea Gray, 1840

Order Euryalida Lamarck, 1816

Family Gorgonocephalidae Ljungman, 1867

Genus *Gorgonocephalus* Leach, 1815

<sup>1</sup>\**Gorgonocephalus arcticus* Leach, 1819 (Fig. 1)

*Astrophyton agassizi*: Lyman, 1865: 186.

*Gorgonocephalus agassizii*: Lyman, 1882: 264.

*Gorgonocephalus arcticus*: Döderlein, 1911: 103; Koehler, 1924: 231; Mortensen, 1933: 9; D'yakonov, 1954: 27; Smirnov and Smirnov, 1990: 446; 1994: 161; Anisimova and Cochrane, 2003: 126.

**Material examined.** Korea: 1 specimen, Gonghyeonjin Port, Gonghyeonjin-ri, Jugwang-myeon, Goseong-gun, Gangwon-do, 12 Nov 2013, at 250 m depth by fishing net; 1 specimen, Daejin Port, Hyeonnae-myeon, Goseong-gun, Gangwon-do, 29 Aug 2014, at 300 m depth by fishing net.

**Description.** Disk with thin plates, covered with many small granules, with a row of marginal plates on interbranchial outer margin (Fig. 1A, B). Especially, radial shields and dorsal side of arms densely covered with granules of various sizes (Fig. 1C, H). Radial shields have different lengths and widely concave features tapering towards center of disk. One madreporite left a trace on corner of ventral side of disk (Fig. 1I). Three or four arm spines exist between arm segments on ventral side of arm. Arm spine short, cylindrical, with many small pores, half of corresponding arm segment (Fig. 1F, G), becoming hooks with two or three pointed tips near end of arm (Fig. 1J–M). Oral parts composed of sharp spiniform teeth (Fig. 1D, E).

**Size.**  $R = 2.5$  cm,  $r = 1.5$  cm,  $R/r = 1.6$ .

**Color.** Color is yellow ocher in life and is light brown in alcohol.

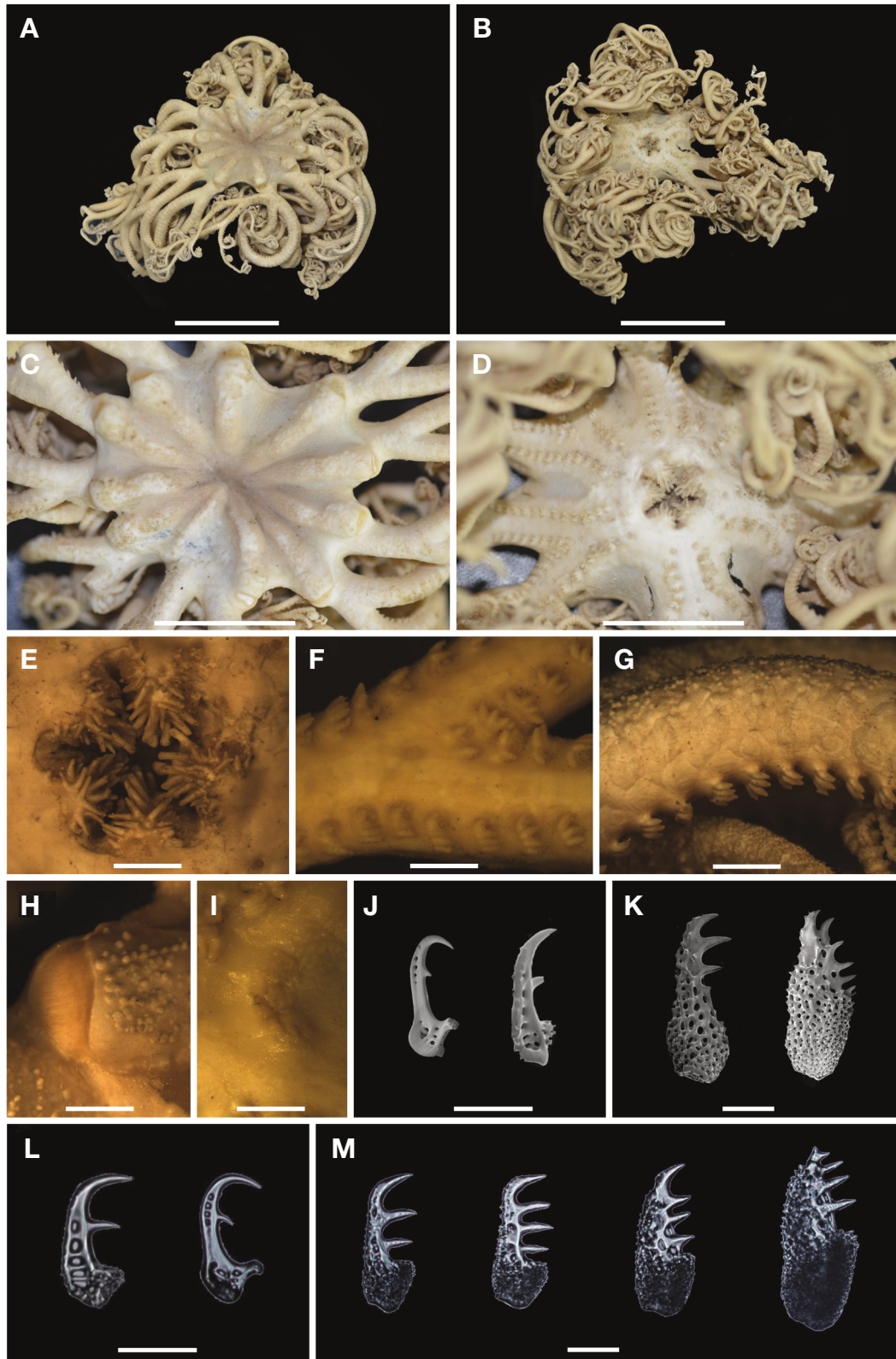
**Distribution.** Korea (East Sea), Siberian East Coast, Arctic Ocean (Greenland, Spitzbergen, Barents Sea, White Sea, Kara Sea, Franz Josef Land), North America, Norway, Gulf of Mexico.

**Remarks.** This northern basket star is an endemic arctic species usually distributed in the cold boreal zone around the northwest North Atlantic Ocean (Piepenburg, 2000), and

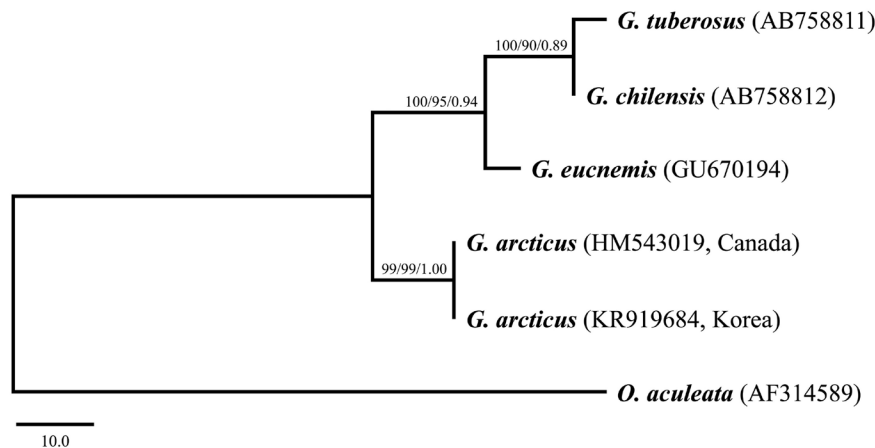
**Table 1.** Polymorphic sites between Korean *G. arcticus* and four *Gorgonocephalus* species obtained from NCBI

[illegible]

The total aligned sequence number was 569 bp. There were no sequence differences between KR919684 (Korea) and HM543019 (Canada).



**Fig. 1.** *Gorgonocephalus arcticus*. A, C, Dorsal view; B, D, Ventral view; E, Oral part; F, Ventral side of arm; G, Lateral side of arm; H, Distal part of radial shield; I, Madreporite; J, K, Arm spines under scanning electron microscope; L, M, Arm spines under light microscope. Scale bars: A, B=2.5 cm, C, D=1.4 cm, E-I=3 mm, J-M=50 µm.



**Fig. 2.** Maximum parsimony tree inferred from mt-COI, showing phylogenetic relationships among four *Gorgonocephalus* species. Bootstrapping values obtained from maximum parsimony, maximum likelihood, and Bayesian inference methods are shown in each node in order. *G. Gorgonocephalus*; *O. Ophiopholis*.

is characterized having a smooth and thick body, distinctly upwelled disk, and acute spiniform teeth.

**Molecular analysis.** A total of 569 base pairs (bp) of mt-COI DNA were obtained from Korean *G. arcticus* (GenBank accession number: KR919684), and perfectly correspond to *G. arcticus* sequence data obtained from NCBI (GenBank HM543019, Canada). There were partial sequence gaps comparing to each sequence of other *Gorgonocephalus* species obtained from NCBI: difference as 36 bp from *G. tuberosus* (GenBank AB758811), difference as 32 bp from *G. chilensis* (GenBank AB758812), and difference as 25 bp from *G. eucnemis* (GenBank GU670194) (Table 1). We appointed *Ophiopholis aculeata* as the outgroup, and analyzed the sequence of *G. arcticus* from Korea with those of *G. arcticus*, *G. chilensis*, *G. eucnemis*, and *G. tuberosus* obtained from NCBI. The phylogenetic trees inferred from their alignment sequences by the MP, ML, and BI methods are very similar to each other, with only minor differences (Fig. 2). All trees confirm that the Korean species is clearly different from *G. tuberosus*, *G. eucnemis*, and *G. chilensis*, and Korean *G. arcticus* data are coincident with *G. arcticus* of NCBI data of family Gorgonocephalidae.

## ACKNOWLEDGMENTS

This study was supported by the Survey of Korean Indigenous Species funded by MOE (NIBR 201501201), the Development Project of Overseas Marine Biological Resources and their utilization system, the Marine Biotechnology Program (MERBK; Marine Echinoderm Resource Bank of Korea), and the program of Management of Marine Organ-

isms causing Ecological Disturbance and Harmful Effects, funded by KIMST/MOF, Korea.

## REFERENCES

- Anisimova NA, Cochrane SJ, 2003. An annotated checklist of the echinoderms of the Svalbard and Franz Josef Land archipelago and adjacent waters. *Sarcia*, 88:113-135. <http://dx.doi.org/10.1080/00364820310000102>
- Baker AN, 1980. Euryalinid Ophiuroidea (Echinodermata) from Australia, New Zealand, and the south-west Pacific Ocean. *New Zealand Journal of Zoology*, 7:11-83. <http://dx.doi.org/10.1080/03014223.1980.10423763>
- Döderlein L, 1911. Über japanische und andere Euryalae. *Abhandlungen der math. physiology Klasse der K. Bayer Akademie der Wissenschaften, Supplement*, 5:1-123.
- D'yakonov AM, 1954. Ophiuroids of the USSR Seas. *Academy Science USSR*, 55:1-136.
- Kim D, Shin S, 2015. A newly recorded basket star of genus *Gorgonocephalus* (Ophiuroidea: Euryalida: Gorgonocephalidae) from Korea. *Korean Journal of Environmental Biology*, 33:205-208. <http://dx.doi.org/10.11626/KJEB.2015.33.2.205>
- Koehler R, 1924. *Les Echinodermes des mers d'Europe*, tome 1. Librairie Doin, Paris, pp. 1-362.
- Lee T, Shin S, 2011. A new record of sea urchin (Echinoidea: Camarodonta: Strongylocentrotidae) based on morphological and molecular analysis in Korea. *Korean Journal of Systematic Zoology*, 27:213-219. <http://dx.doi.org/10.5635/KJSZ.2011.27.3.213>
- Lyman T, 1865. Ophiuridae and Astrophytidae. *Illustrated Catalogue of the Museum of Comparative Zoology at Harvard College*, 1:1-200.

- Lyman T, 1882. Report on the Ophiuroidea dredged by H.M.S. Challenger during the years 1873-76. Report on the Scientific Results of the Voyage of H.M.S. Challenger during the Years 1873-76, Zoology, 5:1-386.
- Matsumoto H, 1917. A monograph of Japanese Ophiuroidea arranged according to a new classification. Journal of the College of Science, Imperial University of Tokyo, 38:1-408.
- Mortensen T, 1933. Ophiuroidea. Danish Ingolf-Expedition, 4:1-121.
- Okanishi M, Fujita T, 2013. Molecular phylogeny based on increased number of species and genes revealed more robust family-level systematics of the order Euryalida (Echinodermata: Ophiuroidea). Molecular Phylogenetics and Evolution, 69:566-580. <http://dx.doi.org/10.1016/j.ympev.2013.07.021>
- Piepenburg D, 2000. Arctic brittle stars (Echinodermata: Ophiuroidea). Oceanography and Marine Biology: An Annual Review, 38:189-256.
- Shin S, 2013. Invertebrate fauna of Korea. Feather stars, basket stars. National Institutes of Biological Research Korea, 32:1-105.
- Shin S, Rho BJ, 1996. Illustrated encyclopedia of fauna and flora of the Korea, Vol. 36. Echinodermata. Ministry of Education, Seoul, pp. 1-780.
- Smirnov AV, Smirnov IS, 1990. Echinoderms from the Laptev Sea. Issledovaniya Fauny Morei, 37:411-462.
- Smirnov AV, Smirnov IS, 1994. Echinoderms from the East-Siberian Sea. Issledovaniya Fauny Morei, 49:132-182.
- Stöhr S, 2015. Gorgonocephalidae Ljungman, 1867. In: Stöhr, S., O'Hara, T. & Thuy, B. (Eds.). World Ophiuroidea database. World Register of Marine Species, Accessed 1 Oct 2015, <<http://www.marinespecies.org/aphia.php?p=taxdetails&id=123203>>.

Received March 30, 2015  
Revised October 12, 2015  
Accepted October 12, 2015